ROBUST FOREIGN OBJECTS DETECTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. provisional application Ser. No. 62/245,378, filed Oct. 23, 2015, titled "Foreign Objects Detection," and U.S. provisional application Ser. No. 62/245,381, filed Oct. 23, 2015, titled "Robust Foreign Object Detection," each of which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] 1. Technical Field

[0003] The techniques described herein relate generally to wireless power delivery, and particularly to detection of foreign objects in the field produced by a wireless power transmitter.

[0004] 2. Discussion of the Related Art

[0005] Wireless Power Transfer Systems (WPTS) are gaining increasing popularity as convenient way to deliver power without wires or connectors. WPTS currently under development in the industry can be separated in two major classes: magnetic induction (MI) systems and magnetic resonance (MR) systems. Both types of systems include a wireless power transmitter and a wireless power receiver. Such systems can be used to power or charge mobile devices such as smartphones or tablet computers, among other applications.

[0006] Inductive WPTS typically operate in an allocated frequency range of several hundred kilohertz using frequency variation as a power flow control mechanism. MR WPTS typically operate on a single resonant frequency using input voltage regulation to regulate output power. In typical applications, MR WPTS operate at a frequency of 6.78 MHz.

[0007] Several industry committees have been working on developing international standards for consumer products based on wireless power transfer.

SUMMARY

[0008] Some embodiments relate to a foreign object detection method for a wireless power transmitter having a matching network and transmit coil. The method includes (A) energizing the matching network and transmit coil and exciting resonance between the matching network and transmit coil; (B) allowing the resonance to decay; (C) measuring a temporal characteristic of the decay; and (D) analyzing the temporal characteristic to determine whether a foreign object is coupled to an electromagnetic field generated by the transmit coil.

[0009] Some embodiments relate to at least one non-transitory computer readable storage medium having stored thereon instructions, which, when executed by a processor, perform the foreign object detection method.

[0010] Some embodiments relate to an apparatus for performing foreign object detection for a wireless power transmitter having a matching network and transmit coil. The apparatus includes circuitry configured to: (A) energize the matching network and transmit coil and excite resonance between the matching network and transmit coil; (B) allow the resonance to decay; (C) measure a temporal characteristic of the decay; and (D) analyze the temporal characteristic to determine whether a foreign object is coupled to an electromagnetic field generated by the transmit coil.

[0011] Some embodiments relate to an apparatus for driving a wireless power transmitter and performing foreign object detection. The apparatus includes a drive circuit configured to energize a matching network and transmit coil of the wireless power transmitter, excite resonance between the matching network and transmit coil, and allow the resonance to decay. The apparatus also includes a controller configured to measure a temporal characteristic of the decay and analyze the temporal characteristic to determine whether a foreign object is coupled to an electromagnetic field generated by the transmit coil.

[0012] The foregoing summary is provided by way of illustration and is not intended to be limiting.

BRIEF DESCRIPTION OF DRAWINGS

[0013] In the drawings, each identical or nearly identical component that is illustrated in various figures is represented by a like reference character. For purposes of clarity, not every component may be labeled in every drawing. The drawings are not necessarily drawn to scale, with emphasis instead being placed on illustrating various aspects of the techniques and devices described herein.

[0014] FIG. **1** shows a block diagram of a wireless power system including a wireless power transmitter and a wireless power receiver.

[0015] FIG. **2** shows a flowchart of a method of performing foreign object detection.

[0016] FIGS. **3**A-**3**C show examples of a drive circuit implemented as class D amplifiers.

[0017] FIGS. **4**A-**4**C show examples of a drive circuit implemented as class E amplifiers.

[0018] FIG. **5** shows an example of wireless power reception circuitry for a wireless power receiver.

[0019] FIG. **6** shows waveforms for an example in which stimulus is performed by switching the inverter of FIG. **3**C at a single switching frequency and supply voltage VDC, with no wireless power receiver present.

[0020] FIG. **7** shows waveforms for an example similar to FIG. **6** in which a wireless power recover is present in the field produced by the wireless power transmitter.

[0021] FIG. **8** shows an example of a stimulus that can fully charge the rectifier filter capacitor Crec.

[0022] FIG. **9** shows an example of a double stimulus in which the switching frequency is changed.

[0023] FIG. **10** shows an example of a double stimulus in which the supply voltage is changed.

[0024] FIG. **11** shows an example of a double stimulus in which both the switching frequency and supply voltage are changed.

[0025] FIG. **12** shows an example of continuous time measurements.

[0026] FIG. **13** shows an example of discrete time measurements.

DETAILED DESCRIPTION

[0027] Wireless power transfer can be degraded due to the presence of a foreign object in the field produced by the wireless power transmitter. Conductive objects such as metallic objects may absorb power due to the inducement of eddy currents in the conductive object. The presence of such an object can significantly degrade the efficiency of the